Simultaneous Acoustic/Microwave Studies of Bound and Breaking Waves in a Wave Tank

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Grant Number: N00014-98-1-0072
http://nt-waves.apl.washington.edu

LONG-TERM GOALS

The long-range objective of this project is to understand both acoustic and microwave scattering from rough water surfaces sufficiently well to be able to implement them in operational models and, if possible, to remotely sense microscale breaking on the sea surface.

SCIENTIFIC OBJECTIVES

The scientific objectives of this research are to apply acoustic and microwave techniques of surface backscatter to investigate the bound and breaking waves that have been shown to exist on rough water surfaces, both in the laboratory and on the ocean. The work is particularly aimed at determining the angular dependence of bound waves and their relationship to microscale breaking waves.

APPROACH

Our approach is to observe both acoustic and microwave backscattering from wind-roughened water surfaces in wind wave tanks, and to model the surface in a manner that will explain both types of scattering. The acoustic and microwave systems used are fully coherent so that Doppler spectra as well as backscattering cross sections can be obtained. Our wave tank arrangements are designed so that the acoustic and microwave systems both observe the surface at the same incidence angle. We use acoustic and microwave systems whose transmitted wavelengths are within 10% of each other. Previous work has been carried out with 0.8 cm and 2 cm radiation in the UW wind wave tank looking upwind and downwind. In order to observe the angular dependence of the backscatter and to attempt to view breaking waves, however, this year’s work was carried out in the large wind wave facility in Marseilles, France.

WORK COMPLETED

Prior to FY00, we had carried out measurements in the UW wavetank at 0.8 and 2 cm looking both up and downwind. The results of the measurements at 0.8 cm clearly showed that the backscatter could be

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2001**	2. REPORT TYPE	3. DATES COVERED **00-00-2001 to 00-00-2001**

4. TITLE AND SUBTITLE **Simultaneous Acoustic/Microwave Studies of Bound and Breaking Waves in a Wave Tank**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Applied Physics Laboratory,,University of Washington,1013 NE 40th St,,Seattle,,WA, 98105-**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The long-range objective of this project is to understand both acoustic and microwave scattering from rough water surfaces sufficiently well to be able to implement them in operational models and, if possible, to remotely sense microscale breaking on the sea surface.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

explained as Bragg scattering from parasitic capillary waves riding on the front faces of longer waves. This result has now been published in the Journal of Geophysical Research (Plant et al., 1999c). Scattering from 2 cm waves does not appear to be due to parasitic capillary waves, however, and analysis of these data is continuing.

We carried out a series of measurements in the large wind wave tank in Marseilles, France in July and August of last year. Unfortunately, the fan motor failed in the middle of our measurement series and was not back in operation until October. During the summer, after the failure of the fan, we turned to the observation of propagating breaking waves using simultaneous microwave and acoustic backscattering. Frequency chirped trains of paddle-generated waves were produced in the tank in such a manner that their breaking location could be controlled. We observed backscatter before, during, and after breaking events.

We returned to Marseilles in November, after the fan was repaired, to complete our measurements of wind waves. Microwave and acoustic data were collected with both 8 mm and 2 cm radiation at a variety of incidence angles, azimuth angles, and wind speeds.

RESULTS

Some results of our measurements using breaking waves were reported last year. This year, we concentrated on results from the wind wave studies carried out in November 2000. Data were collected at incidence angles of 30 to 50 degrees in steps of 5 degrees, azimuth angles of 0 to 180 degrees in steps of 30 degrees, and nominal wind speeds of 3, 4, 5, 6, 8, 10, and 12 m/s. Most data were taken at a fetch of 25.5 m with the microwave and acoustic systems set at the same incidence angles and having the same horizontal look direction. A few sets of data were taken with the sonar and radar having opposite horizontal look directions and one complete set of 2 cm data was collected at a fetch of 6.3 m.

The figures below show Doppler spectra collected during some of these runs. The data illustrated are for a 2 cm wavelength, the wind speed increases from left panel to right, and the azimuth angle changes from one row to the next. These spectra illustrate the dependence of bound wave intensity on wind speed and azimuth angle. At low wind speeds nearly all Doppler spectra demonstrate the primary characteristic of Bragg scattering from freely propagating waves: a single prominent spectral peak at the frequency of the Bragg wave. As the wind speed increases, a second line offset farther from zero begins to appear. When the systems have a component of look that is upwind (Fig.1), this second peak is prominent in the radar spectra but is not seen in the sonar; it is most prominent when the radar is pointed directly upwind, at Radar Az = 0. When looking downwind (Fig.2), the higher-wind sonar spectra show the second peak but the radar spectra do not.

We account for the appearance of the second peak by postulating that it is due to short bound wave that ride on the leeward face of the dominant wave and therefore exhibit a non-zero mean tilt. This causes the local incidence angle of the radar at the location of these bound waves to be smaller than that of the sonar. Thus bound wave signatures appear more strongly in the radar spectrum than in the sonar spectrum when the systems look upwind. When looking downwind, the converse is true. By examining the intensities of the free and bound wave peaks in the spectra as functions of wind speed and azimuth angle, we will be able to determine the relative importance of scattering from these two types of surface waves for the different conditions.

IMPACT/APPLICATION

The results of this work support previous measurements that have shown the importance of bound, tilted short waves for understanding rough surface scattering both in wind wave tanks and on the ocean (Plant, 1997; Plant et al., 1999a; Plant et al., 1999b). Although we have not demonstrated it in this report, a variety of data, including our Marseilles data, show that bound wave effects are more prominent at high incidence angles than at low ones. Thus their effects are important for developing scattering models at moderate to high incidence angles, especially at horizontal polarization. Abundant evidence exists that signatures of surface and subsurface vessels appear most prominently in microwave imagery taken at horizontal polarization and high incidence angles. Bound waves are undoubtedly one reason for this. Thus the work carried out in this project is directly applicable to non-acoustic ASW and other ocean imaging.

TRANSITIONS

The results of this project have not yet been transitioned for operational use.

RELATED PROJECTS

This project has many parallels with a project run by the Office of the Secretary of Defense to investigate the microwave signatures produced by submarines. The basic understanding of microwave scattering, especially at high incidence angles, produced in this project furthers these attempts to detect submarines.

Finally, knowledge of acoustic scattering obtained from this joint microwave/acoustic study benefits programs on acoustic scattering from the sea surface and near-surface bubbles sponsored by ONR Code 321OA.

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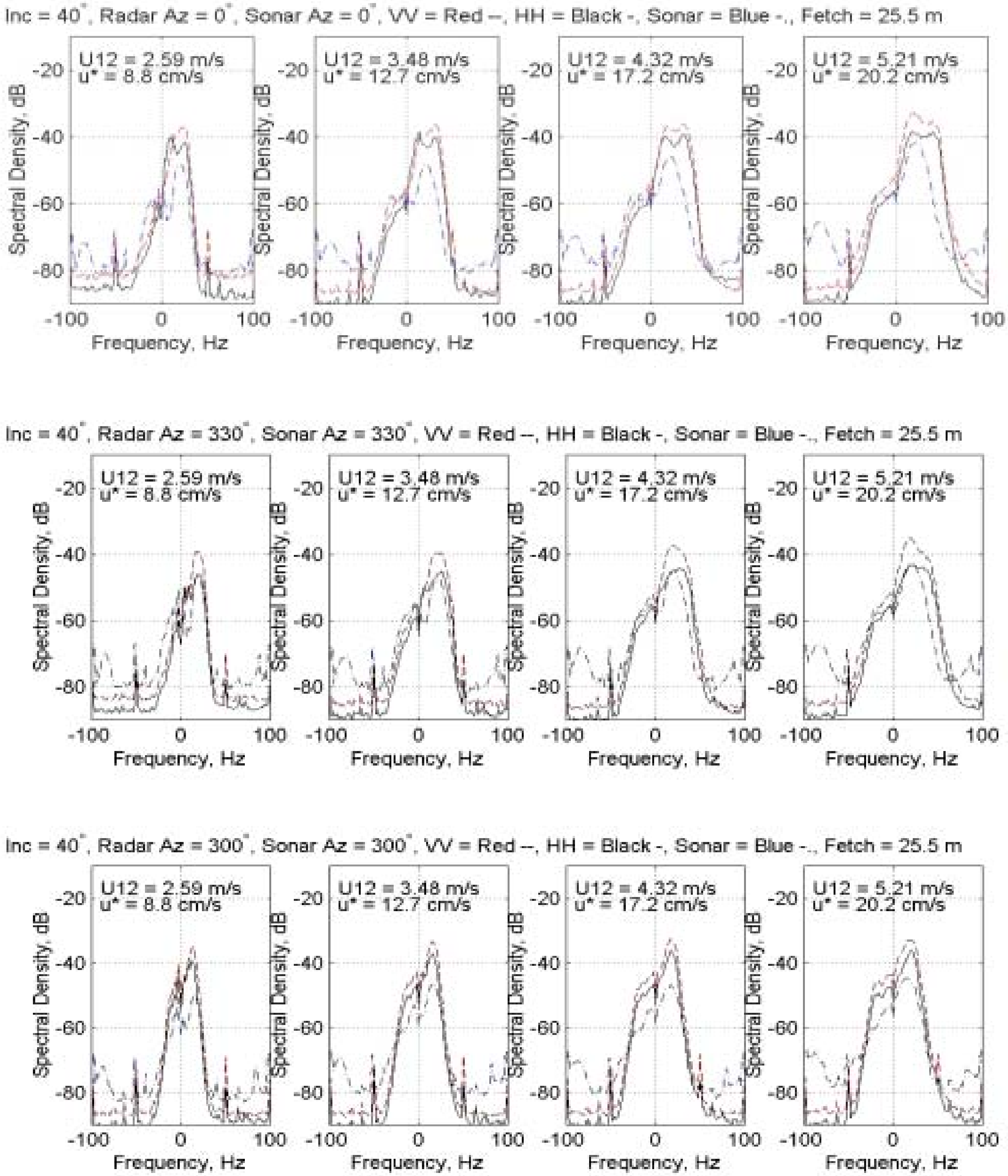

Figure 1. Radar and sonar Doppler spectra taken in the Marseilles Wind Wave tank at various azimuth angles with an upwind component

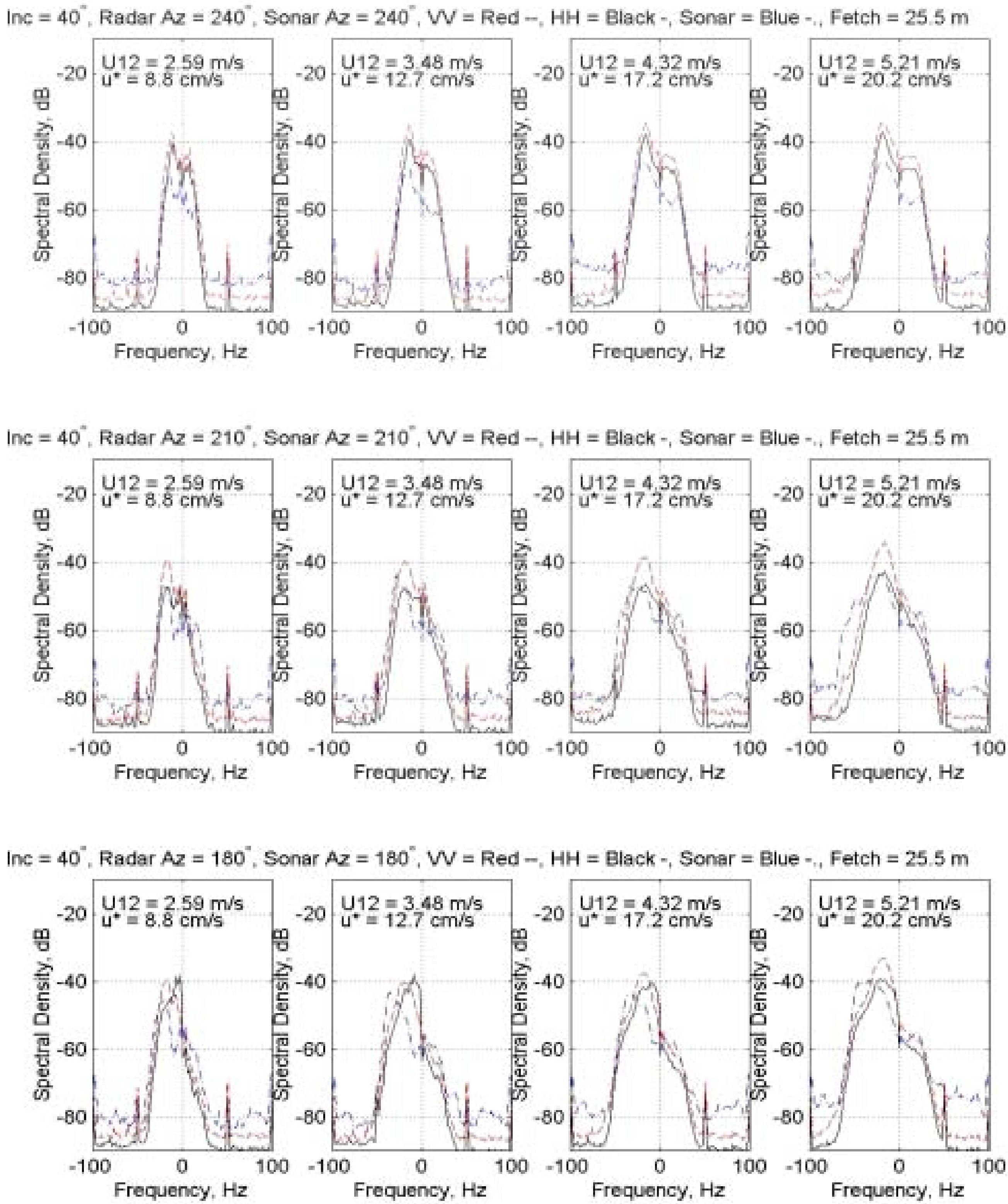

Figure 2. Radar and sonar Doppler spectra taken in the Marseilles Wind Wave tank at various azimuth angles with an downwind component